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ARCEUTHOBIUM TSUGENSE

HEMLOCK DWARF MISTLETOE

A Species of Special Concern?

Diane M. Hildebrand

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by

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ARCEUTHOBIUM TSUGENSE, Hemlock Dwarf Mistletoe

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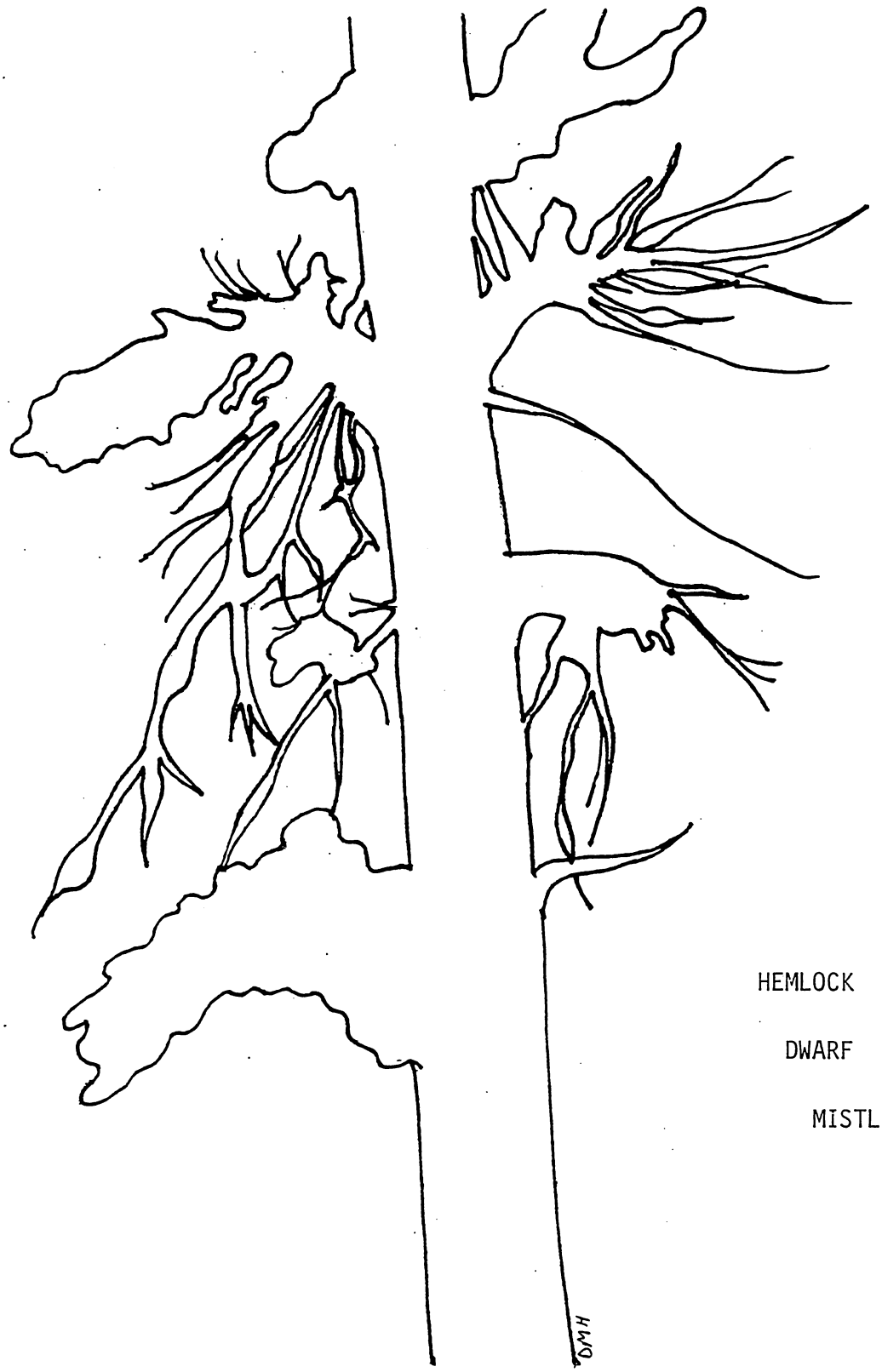

HEMLOCK

DWARF

MISTLETOE

ARCEUTHOBIUM TSUGENSE
HEMLOCK DWARF MISTLETOE

SUMMARY

Arceuthobium tsugense, hemlock dwarf mistletoe, is listed (Table C-3, Record of Decision and Standards and Guidelines for Management within Range of the Northern Spotted Owl, Forest Service and Bureau of Land Management, April 1994) as a species requiring survey and manage strategies 1 and 2: "Manage known sites" and "Survey before ground disturbing activities, and manage sites." These strategies are intended for species associated with late-successional and old-growth forests, and whose habitat or populations are strongly limited or at high risk of becoming limited due to management activities. These strategies are inappropriate for both subspecies of hemlock dwarf mistletoe. Survey and manage strategy 4, "Conduct General Regional Surveys" is appropriate for A. tsugense subsp. mertensianae, mountain hemlock dwarf mistletoe, only in Washington. No other survey and manage requirements are appropriate for A. tsugense.

Dwarf mistletoes spread by forcibly discharged seed, with some long distance dispersal aided by birds. Dwarf mistletoes are host-specific, obligate parasites that readily infect all ages and sizes of host trees. The amount of dwarf mistletoe in a stand tends to increase over time, as the parasite reproduces and spreads within and between host trees until interrupted by fire or other disturbance. However, some of the largest numbers of infected trees per acre can be found in young stands managed without adequate regard for dwarf mistletoe. Dwarf mistletoes are limited by host distribution and climatic factors, including light and length of growing season. Dwarf mistletoes do not require habitat components that are contributed by late successional and old-growth forests.

Hemlock dwarf mistletoe causes branch and bole swelling, witches' broom formation, growth loss, wood deformity, and early mortality. Silvicultural control, although technically straightforward, can be difficult in practice, especially for Federal land managers. Clean harvesting without leaving residual trees would greatly reduce or eliminate infection. Maintaining rapid tree height growth and relatively short rotations (less than 100 years) would allow good timber production in the presence of dwarf mistletoe. However, managing stands with many residual trees over long rotations, requires that dwarf mistletoe infection in young stands be kept very light. Because of the relatively short time required for seed production (4 to 5 years), and the latent period between infection and readily-visible symptoms (3 years), early overstory removal and two sanitation thinnings are necessary to reduce hemlock dwarf mistletoe to acceptable levels for timber production. Because repeated sanitations are seldom accomplished, and young dwarf mistletoe infections may be difficult to recognize, western hemlock stands entered for timber harvest have tended to show increases in infection severity.

Hemlock dwarf mistletoe has two subspecies: A. tsugense subsp. tsugense, commonly called western hemlock dwarf mistletoe; and A. tsugense subsp. mertensianae, commonly called mountain hemlock dwarf mistletoe. In addition to the hemlocks, principal hosts for both subspecies include Pacific silver fir, subalpine fir, and noble fir.

Western hemlock dwarf mistletoe is common and well distributed in the Coast and Cascade ranges of Oregon and Washington, becoming less common in northern California. Most of the western hemlock type in California is on non-federal land, where 3 percent of the volume of western hemlock is infested with dwarf mistletoe. In Oregon and Washington National Forests within range of the northern spotted owl, over 26 percent of timber inventory plots with western hemlock had dwarf mistletoe on western hemlock.

Mountain hemlock dwarf mistletoe is common and well distributed in the Cascade Mountains throughout Oregon, becoming less common toward central California. In Oregon National Forests within range of the northern spotted owl, 25 percent of timber inventory plots with mountain hemlock had dwarf mistletoe on mountain hemlock. In northern California, timber inventory on the Shasta-Trinity National Forest reports 2 percent of the basal area of mountain hemlock as infected with dwarf mistletoe. Distribution of mountain hemlock dwarf mistletoe in the northern Cascade and Coast Ranges in Washington is not well understood. Timber inventory reports dwarf mistletoe on mountain hemlock on 10 percent of plots with mountain hemlock on the Gifford Pinchot National Forest, 14 percent on the Mt. Baker-Snoqualmie National Forest, 11 percent on the Okanogan National Forest, almost 9 percent on the Olympic National Forest, and 12 percent on the Wenatchee National Forest. Although these percentages tend to indicate common occurrence and wide distribution in Washington, verification of the taxonomic identity of the dwarf mistletoe is needed.

BACKGROUND: SURVEY AND MANAGE GUIDELINES

The Record of Decison and Standards and Guidelines (ROD) for Management of Forest Service and Bureau of Land Management Lands within Range of the Northern Spotted Owl (Forest Service and Bureau of Land Management, 1994) includes survey and manage provisions. These provisions require "certain actions relative to rare species of plants and animals" (ROD page 11). The actions required are intended to "protect" species listed on Table C-3 in the ROD (page C-49). Species included in the listing were those the scientific assessment panels considered associated with late-successional and old-growth forests, and not adequately protected by management plans. The intent of the survey and manage provisions is to maintain the viability of the species.

The survey and manage provisions include four components or strategies: 1) Manage known sites; 2) Survey prior to ground-disturbing activities; 3) Conduct extensive surveys and manage sites; 4) Conduct general regional surveys.

The listing in Table C-3 in the ROD includes Arceuthobium tsugense with strategies 1) Manage known sites, and 2) Survey prior to ground-disturbing activities.

The inclusion of A. tsugense on the list was based mainly on the information [in need of updating] provided in Appendix J2, Results of Additional Species Analysis (J2) (Holthausen, et al., 1994), that was published two months before the ROD. According to J2 (pages J2-253 to J2-255), A. tsugense

> "occurs primarily on western hemlock, in old to very old old-growth forests, most commonly in stands greater than 600 years. A recently described

subspecies, (subsp. mertensianae) grows on mountain hemlock, while the subspecies tsugense occurs typically on western hemlock and shore pine."
"Harvest of many of the forests over 700 years [age] has considerably reduced habitat for this species."
"None of the alternatives were considered to have any likelihood of having this species well distributed throughout its range. This species is rare throughout its range."

The report in J2 lists three "knowledgeable individuals" with regard to A. tsugense. Interviews with these knowledgeable individuals provided the statements included in Appendix A of this paper.

The formal request for a change in status of A. tsugense was written as a memo by members of the Vascular Plant subgroup on February 24, 1995. After signing, the request was submitted to Cheryl McCaffrey, Survey and Manage Work Group Leader, on March 2, 1995. A copy of the memo is attached as Appendix C. The bulk of this paper was submitted with the memo as supporting documentation. The Survey and Manage Work Group and the Vascular Plant subgroup are interagency teams working for the Regional Ecosystem Office. The interagency executives (RIEC) must make the decision on changing the status of a species.

OBJECTIVES OF THIS PAPER

The purpose of this paper is to provide sufficient additional information to support a change in the status of A. tsugense. The recommended change in status is removal of the listing for Arceuthobium tsugense, and in its place listing A. tsugense subsp. mertensianae with survey and manage strategy 4, "Conduct general regional surveys", only in Washington.

The ROD (p. 37) allows changes in the Survey and Manage guidelines:
"These changes could include changing the schedule, moving a species from one survey strategy to another, or dropping this mitigation requirement for any species whose status is determined to be more secure than originally projected. The REO (Regional Ecosystem Office) will forward such proposals, along with recommendations, to the RIEC (Regional Interagency Executive Committee) for action. The RIEC may recommend such changes as appropriate in order to assure the continuing attainmant of the purposes of the plan and the conservation requirements of all laws applicable to the affected species."

This paper updates information on both subspecies of A. tsugense, including their wide host ranges, infection in all age classes of hosts, and common distribution throughout most of their ranges. Only in the Coast and Cascade Ranges in the northern part of the range of mountain hemlock dwarf mistletoe, A. tsugense subsp. mertensianae, is there some question about its distribution. Management activities are not a threat to the species or the two subspecies, their viability or their habitat quality or abundance.

DWARF MISTLETOE BIOLOGY AND LIFE CYCLE

Dwarf mistletoes, Arceuthobium spp., are seed-bearing vascular plants in the family Viscaceae, and are obligate parasites on conifers in the northern hemisphere. They are dioecious, with male and female plants occuring in about the same proportions for most dwarf mistletoes. In A. tsugense the proportion of adult female plants differs by host (Wiens et al., 1995, in review).

Dwarf mistletoe plants are small and leafless, consisting of aerial shoots that protrude from host tree branches and boles. Shoots originate from an endophytic system imbedded in host tissues. The endophytic system is described and illustrated by Alosi and Calvin (1984). The "strands" of the endophytic system grow longitudinally and sometimes circumferentially through the host cortex and outer phloem. Radially oriented "sinkers" extend into the xylem. At the cambium, a meristem in the sinker ensures simultaneous elongation of the sinker as secondary vascular tissues are formed in the host tree.

Female plants produce berries usually with one seed per fruit. When the fruit is nearly mature it begins to swell. When the fruit is mature, the berry drops and discharges the seed (by hydrostatic pressure) outward and upward at an initial velocity of about 90 ft per second (Hawksworth and Wiens, 1972). Discharged seeds can travel horizontally about 30 to 40 ft, although the average distance is about 15 ft from the infection source. Seeds shooting out from the tops of trees and aided by wind rarely travel as far as 100 ft (Scharpf and Hawksworth, 1993).

Seeds are coated with viscin, a sticky, hygroscopic substance. Needles of coniferous hosts intercept seeds. Precipitation lubricates the viscin, and the seed eventually slides down the needle and sticks to the twig, or falls to the ground. Germination for most species of Arceuthobium occurs in spring. The germinating radicle forms a holdfast that develops a wedge capable of mechanically penetrating relatively young, thin host tissues (Hawksworth and Wiens, 1972). Radicles are negatively phototropic, positively thigmotrophic and geotropically neutral (Knutson 1984). A dwarf mistletoe infection becomes established when the endophytic system begins to grow in host tissues.

Long distance dispersal, although relatively rare, is effected by birds and small mammals (Nicholls, Hawksworth, and Merrill, 1984). Animals are struck by the sticky seeds, and remove them during preening, often wiping them on twigs. Birds perch in tree tops and preen, and the tops of conifers contain a high proportion of young tissues susceptible to infection. Dwarf mistletoe infection in the upper crown has the greatest potential for spread to surrounding trees.

HOST RESPONSE TO DWARF MISTLETOE INFECTION

Hawksworth and Wiens (1972) and Scharpf and Hawksworth (1993) discuss host tree reponse to dwarf mistletoe infection, which begins as localized swelling of branches. Sometimes pronounced swelling of the bole results from direct

infection of the bole or from the endophytic system growing in from an infected branch. In firs and hemlocks, wood decay fungi often enter bark cracks and openings in the swellings.

After several years, host branches usually react to dwarf mistletoe infection by producing a witches' broom. A broom is an abnormal proliferation of many small twigs on a branch that appears as a clustered mass of twigs and foliage (Scharpf and Hawksworth, 1993). Brooms monopolize water and nutrients at the expense of the rest of the tree.

NOMENCLATURE

Synonymy

Synonyms for Arceuthobium tsugense (Rosendahl) G. N. Jones include Razoumofskya tsugensis Rosendahl, Razoumofskya douglasii tsugensis (Rosendahl) Piper, Arceuthobium douglasii Engelm. var. tsugensis (Rosendahl) M. E. Jones, and Arceuthobium campylopodum Engelm. forma tsugensis (Rosendahl) Gill. Hawksworth and Wiens (1972) describe the nomenclature:

> "The name tsugensis was published as a species of Razoumofskya; however, the Botanical Rules of Nomenclature require that the gender of generic and specific names agree, so with the transfer to Arceuthobium the correct name became tsugense. This mistletoe has been variously treated as a distinct species, or as allied to A. douglasii or A. campylopodum."

Subspecies

Current taxonomic treatment of A. tsugense, hemlock dwarf mistletoe, includes two subspecies. Subspecies tsugense is commonly referred to as western hemlock dwarf mistletoe, and subspecies mertensianae, as mountain hemlock dwarf mistletoe (Hawksworth et al., 1992).

HOSTS

Hawksworth and Wiens (1972) listed Tsuga heterophylla and T. mertensiana as the principal hosts of Arceuthobium tsugense, "although several other trees are attacked, particularly when they grow in association with infected hemlocks: Abies lasiocarpa, A. amabilis, A. grandis, A. procera, Pinus contorta subsp. contorta, P. albicaulis, and P. monticola." They reported A. tsugense as "fairly common" on Abies amabilis, and that many reports of fir dwarf mistletoe (Arceuthobium abietinum) in Washington, are actually hemlock dwarf mistletoe. A. tsugense occurs rarely on Picea sitchensis (Alaska and British Columbia), on Picea breweriana (northern California), and Picea engelmanii (Oregon Cascades).

Arceuthobium tsugense subsp. tsugense

According to Scharpf and Hawksworth (1993), Arceuthobium tsugense subsp. tsugense infects western hemlock and associated noble fir and Pacific silver fir. Mountain hemlock is very rarely infected. A local race of A. tsugense subsp. tsugense occurs on shore pine on Orcas Island in Washington and coastal British Columbia.

Mathiasen (1994) provides an updated host list: Principal hosts of Arceuthobium tsugense subsp. tsugense include Abies amabilis, A. lasiocarpa var.lasiocarpa, A. procera, and Tsuga heterophylla. Occasional hosts include Abies grandis and Pinus contorta subsp. latifolia. Rare hosts include Larix occidentalis, Picea engelmannii, P. sitchensis, Pinus monticola, Pseudotsuga menziesii, and Tsuga mertensiana. For the shore pine race of western hemlock dwarf mistletoe, the principal host is Pinus contorta subsp. contorta, and rare hosts are Pinus monticola and Tsuga heterophylla.

On the Mt. Hood National Forest extensive infection of true firs by western hemlock dwarf mistletoe occurs in stands with little or no hemlock (pers. communication, J. S. Beatty, 11/94, USDA For. Serv., Westside Technical Center, Troutdale, OR).

Arceuthobium tsugense subsp. mertensianae

According to Scharpf and Hawksworth (1993), Arceuthobium tsugense subsp. mertensianae infects mountain hemlock and associated western white pine. Other hosts in the Oregon Cascades include noble fir, Pacific silver fir, subalpine fir, and whitebark pine. (Scharpf and Hawksworth, 1993)

Mathiasen (1994) provides an updated host list: Principal hosts of Arceuthobium tsugense subsp. mertensianae include Abies amabilis, A. procera, A. lasiocarpa var. lasiocarpa, and Tsuga mertensiana. Pinus albicaulis is a secondary host, and P. monticola an occasional host. Rare hosts of mountain hemlock dwarf mistletoe include Picea breweriana, Pinus contorta subsp. latifolia, and Tsuga heterophylla.

In the central Oregon Cascades, mountain hemlock dwarf mistletoe commonly occurs in stands of true firs, particularly Pacific silver fir (Abies amabilis), with little or no mountain hemlock (pers. communication, R. L. Mathiasen, 2/95, Idaho Department of Lands, Coeur d'Alene, ID, from Hawksworth trip report,). In southwestern Oregon, mountain hemlock dwarf mistletoe is seen "quite a lot" on P. monticola (pers. communication, D. J.Goheen, 2/95, USDA For. Serv., Southwest Oregon Technical Center, Central Point, OR).

INFECTION CYCLE FOR ARCEUTHOBIUM TSUGENSE

Peak flower production in A. tsugense is usually in late August (Baranyay 1962), then maturation of the fruit requires an average of 13 to 14 months (Smith 1966b). Seed is dispersed from late September to early November (Smith 1966a), and germination of seed occurs from February to May (Smith 1966b).

Smith (1971) summarizes the early symptomology and chronology of infection on western hemlock. Infections become established beginning early in the first growing season after seed dispersal. The first reliable symptom of infection is localized swelling that can be observed as early as the first year. Most swellings become evident the second year. Aerial shoot production begins in the second or third year after dispersal. The first male and female flower production begins in the third year, and flower production is common in the fourth year. On the average, flowering on female shoots occurs 18 months after shoot emergence, and on male shoots 21 months after shoot emergence. Some fruit matures and seeds disperse in the fourth year, and seed production is common in the fifth year (Smith 1971).

For discussion of the silvicultural implications of this infection cycle, see the section on Traditional Silvicultural Management.

A. TSUGENSE EFFECTS ON HOSTS

Negative effects on hosts are generally referred to as "damage". Hemlock dwarf mistletoe causes increased mortality, reduced growth rates, lower wood quality, and increased decay (Packee 1990). According to Buckland and Marples (1952) hemlock dwarf mistletoe on western hemlock reduces vigor and increment (growth rate) of infected trees, reduces wood quality, provides entry points for decay fungi, and increases safety hazards during logging operations. Berntsen (1958) reported A. tsugense on western hemlock as a common parasite that increased mortality especially in mature trees, and reduced growth in trees of all sizes.

On western hemlock, young infections cause small brooms that are not readily observed. With increasing age brooms become massive, up to several hundred pounds. The excessive growth of infected branches drains food resources of the host tree, affecting the tree's growth (Buckland and Marples, 1952). In addition to slow growth, reduced host vigor is sometimes evident in relative response to other agents. On the Pacific coast, western hemlock free of dwarf mistletoe survived successive defoliation by hemlock looper much better than did infected trees (Buckland and Marples, 1952).

Heavy infection by western hemlock dwarf mistletoe results in severe growth loss, deformation, and mortality (Wellwood 1956). These effects are most severe in old-growth stands, but young stands are also damaged in some areas. Brooming of older trees is the most noticeable symptom, and spindle shaped branch swellings also indicate infection. Brooms are often large and abundant in older trees, while smaller trees are often severely stunted. Aerial shoots are not always formed, particularly under the densely shaded conditions of the coastal forests (Scharpf and Hawksworth, 1993).

The effects of mountain hemlock dwarf mistletoe include severe broom formation, growth loss, and mortality. Marked witches broom formation and heavy tree mortality are characteristic (Scharpf and Hawksworth, 1993).

As dwarf mistletoe infections advance the growth rate of the tree declines, particularly after dwarf mistletoe gets into the upper third of the tree crown

(Simes et al., 1972; Wellwood 1956). With sufficient height growth, lightly infected western hemlock may escape growth impact, while heavily infected trees become gradually reduced in growth (Smith 1977).

Dwarf mistletoe infection in western hemlock decreases height growth more than diameter growth (Bloomberg and Smith, 1982). Stem analysis of 30 dominant and codominant western hemlock averaging 110 years old, infected with dwarf mistletoe on a productive site (site 140 at age 100), revealed a 41 percent greater volume growth and 84 percent greater height growth in lightly infected trees compared to severely infected trees (Smith 1969).

On the Thornton T. Munger Research Natural Area in the Wind River Experimental Forest, Gifford Pinchot National Forest, heavy dwarf mistletoe infections weaken and probably kill western hemlock (Debell and Franklin, 1987). In the Wind River Natural Area, Gifford Pinchot National Forest, King (1961) reported that dwarf mistletoe was responsible for the greatest mortality losses in western hemlock. In western hemlock, dieback results from very heavy infection, and stem breakage occurs at large stem infections (Bloomberg and Smith, 1982).

Firs and hemlocks infected by dwarf mistletoe are especially susceptible to decay. Frequently, decaying trees break at dwarf mistletoe swellings, causing loss of timber and presenting hazards to recreationists, vehicles, buildings and other structures (Scharpf and Hawksworth, 1993).

Burls on hemlock caused by A. tsugense can be entrance points for decay fungi, including (rarely) Echinodontium tinctorum (Weir and Hubert 1918). Englerth (1942) reported hemlock dwarf mistletoe infection closely associated with the occurrence of three decay fungi,"Fomes applanatus 77.5%, Fomes hartigii 76.5%, and Ganoderma oregonensis 37.1%," in western Oregon and Washington.

SPREAD AND INTENSIFICATION

In young pure western hemlock stands with overstory residuals infected with dwarf mistletoe, the number of infected young trees doubled every four years. In 10 year old stands infection was about 6 percent, while in 25 year old stands infection increased to about 70 percent (Stewart 1976). In immature western hemlock, the number of new infections per tree per year (rate of intensification) doubled every four years (Richardson and Van Der Kamp, 1972).

Smith (1977) studied spread and intensification in western hemlock planted around an infected residual. Dwarf mistletoe seed production, over-winter retention of seed in tree branches, germination, and infection were variable from year to year. An average of 13 percent of seeds produced resulted in infection. Smith notes that with early removal of infected overstory (before dwarf mistletoe seed production begins in the regeneration), hemlock regeneration that is heavily infected becomes more so mainly through internal reinfection. Intensification in lightly infected trees occurs much more slowly as transfer of seed from the heavily infected trees is limited. Dense foliage intensifies within tree spread and inhibits between tree spread.

In second growth western hemlock, dwarf mistletoe infection level was proportional to the number of residual overstory trees, and inversely proportional to nonhost species present, stand density, and tree growth rate (Bloomberg and Smith, 1982). Open or slow growing stands tend to retain live infections longer than dense or rapidly growing stands. Mortality of dwarf mistletoe infections was greatest on lower slope sites, and least on dry upper slope sites (Bloomberg and Smith, 1982).

In western hemlock, the lowest infection rates correspond to very slow tree growth (dense compact foliage with less seed interception between trees), and rapid tree growth (shading and mortality of infected branches in lower crown, and tree growing faster than internal spread of dwarf mistletoe). Highest infection rates were associated with intermediate tree growth rates (Bloomberg and Smith, 1982).

The slowest spread of western hemlock dwarf mistletoe occurs in dense single-story stands of pure hemlock, and in stands with large components of non-host species. The fastest spread and best development of dwarf mistletoe plants occurs in relatively open, multistoried, pure hemlock stands, where selective logging left infected trees in a range of size classes. Clearcut logging with many small infected residuals left also results in rapid spread of dwarf mistletoe throughout the new stand (Alfaro et al., 1985)

As the host tree grows upward and outward, hemlock dwarf mistletoe infections become buried in the crown, and shading results in fewer shoots and berries. On most infections, maximum seed production occurs within 5 to 10 years, then declines rapidly (Smith 1985).

Hemlock dwarf mistletoe infections located on the outer edge of the crown disperse 70 percent of seeds toward the outside of the tree. Of these, 40 percent escape the crown. Eighty to 90 percent of hemlock dwarf mistletoe seeds are shot upwards rather than downwards (Smith 1985).

Drummond and Hawksworth (1979) reported that hemlock dwarf mistletoe spread and intensification in young stands was at much lower rates in Alaska than in Washington, Oregon, and British Columbia. For discussion of reasons for limitation of dwarf mistletoe in Alaska, see the section Factors Affecting Distribution. Shaw (1982) stated, "At a comparable age, young stands in Alaska appear to be less severely affected by Arceuthobium tsugense than similar stands in Washington, Oregon, and British Columbia."

TRADITIONAL SILVICULTURAL MANAGEMENT

Where management objectives include the growth of reasonably tall host trees of average lifespan, and especially well-formed trees, the silvicultural prescription would include limiting the spread of dwarf mistletoe among young hosts. Removal of infected overstory trees and subsequent removal of infected understory (sanitation) is prescribed.

The silvicultural prescription must consider harvesting practices and harvest boundaries. Small thin-crowned trees left after clearcutting are often infected with dwarf mistletoe that will infect the regeneration (Shea 1966). Infection can also spread in from the edges of stands, as well as from infected advanced reproduction. Roth (1970) points out that partial cutting or not cleaning up after a harvest perpetuates dwarf mistletoe from the residual trees.

Smith (1971) discusses the silvicultural implications of the short life cycle in hemlock dwarf mistletoe:

> "Observations of hemlock mistletoe show that most 1- and 2-year-old infections would remain undetected during sanitation cuts and would not be eradicated except incidentally in the process of eliminating older infections. Assuming that all 3-year and older infections are removed, a minimum of 2 additional years after original cleaning would be required for missed 2-year-old infections to become potential seed bearers. Theoretically, no more than 2 years should elapse between the original and second sanitation cuts, though experimental trials may show that mistletoe can be reduced to an acceptable level with a 3-year interval."

From his studies on overstory spread and intensification of hemlock dwarf mistletoe, Smith (1977) concludes that, assuming infected overstory were removed within 6 years, then 10 well-scattered infected residuals per acre would result in infection of all intervening regeneration. A heavy infection of all intervening trees would result from 35 infected residuals per acre. Removal of infected overstory after 6 years did not prevent high levels of infection, but did modify the rate of intensification.

In their discussion of western hemlock and dwarf mistletoe, Buckland and Marples (1952) describe common management practices. Western hemlock normally regenerates very well naturally after logging, from stand edges and from scattered individuals or patches of non-merchantable trees. They assert that the residual trees are usually infected with dwarf mistletoe, and provide a poor genetic base for the future stand. They report the distribution of hemlock dwarf mistletoe after various stand histories: In extensive clear cut areas (clean), dwarf mistletoe is widely scattered in the reproduction with little economic loss expected in the current rotation. Where occasional individuals or blocks of residual trees were left scattered over the stand, the dwarf mistletoe spread out from the residuals. After selective or high-grade cutting, or where advanced regeneration remained, dwarf mistletoe was present throughout the new stands. They concluded that uneven age stands result in high incidence of dwarf mistletoe and low yields.

Weir (1916) gave the harvest potential of trees infected by dwarf mistletoe at different stages: 1) Infection before tree reaches pole size - tree will probably not be usable as timber; 2) Infection at or shortly after pole size - tree may provide some usable wood, but must be cut early; and 3) Infection in early maturity - tree may not be seriously affected.

At a silvicultural conference, a Forest Service task force described some scenarios that increased the incidence of dwarf mistletoe:

> "Thousands of acres are treated [clearcut followed by burning]. Many were successfully reforested, certified, and written off our management action plans. Meanwhile, many are becoming re-infected from residual

infected whips and from the surrounding infected stands. Follow-up treatments are not scheduled in many cases, because the plantations were certified, and the area assumed to be in top-notch condition..

Another example of management by rote, is the risk tree salvage program which takes dead and down, plus high risk dwarfmistletoe trees - not just once, but time after time. Suddenly, the year comes when it is discovered that there is insufficient overstory to manage, and the area is fully stocked with dwarf mistletoe-infected saplings and poles."

Infected Douglas-fir and western hemlock stands opened up by timber harvest tend to show spectacular increases in infection severity. The task force insisted that management of dwarf mistletoe infected stands could not be accomplished by any rote or cookbook method; prescriptions must be developed for each situation (Simes et al., 1972).

HISTORICAL OCCURRENCE

Dwarf mistletoe on western hemlock was reported as "widespread throughout the hemlock region", and "rendered the hemlock practically worthless" in a few coast districts and cool mountain valleys (Allen 1902).

Hemlock dwarf mistletoe has been repeatedly described as a "common and damaging parasite" on western hemlock (Berntsen 1958, Scott 1962) and on mountain hemlock (Dahms 1958). Roth (1970) states that hemlock dwarf mistletoe "is very wide spread and occurs practically everywhere that western hemlock grows."

In Biology and Classification Dwarf Mistletoes (Arceuthobium), Hawksworth and Wiens (1972) describe the distribution of A. tsugense from near Haines, Alaska, to central California:

"It is found throughout the coastal hemlock forests of Alaska, British Columbia, and Washington. In Oregon, it is common on the west slope of the Cascades, and occurs in California at least as far south as Alpine County in the Sierra Nevada and along the coast to Mendocino County. It is apparently widespread in the coastal mountains of Oregon and California, although few specimens have been collected in these areas."

Drummond and Hawksworth (1979) reported that hemlock dwarf mistletoe occurred as far north as Chilkoot Lake north of Haines, Alaska, at approximately 59 degrees 20 minutes north latitude.

Scharpf and Hawksworth (1993) describe the range of western hemlock dwarf mistletoe as "along the Pacific Coast from southeastern Alaska (near Haines) to northern California (Humboldt County). It is common in the Oregon and Washington Coast and Cascade Ranges but rare in California." They describe the distribution of mountain hemlock dwarf mistletoe, "This mistletoe occurs in the higher elevations of the Cascade Range from central Oregon (Linn County) to the central Sierra Nevada (Alpine County)."

Hawksworth and Wiens (1995, in review) describe the distribution of A. tsugense subsp. mertensianae as "still poorly known, but extends from near Vancouver, British Columbia, through the Cascade Mountains of Washington and Oregon to the central Sierra Nevada in Alpine County, California." This subspecies in known

from a confirmed report in the southern Olympic Mountains, Washington--the first population to be discovered in the Coast Ranges of Washington or Oregon. This dwarf mistletoe is most common in the Cascade Mountains from northern Oregon to central California. Particularly heavy infections on mountain hemlock are noted at Mt. Baker in the northern Washington Cascades, and in the southwestern Olympic Mountains of Washington (Hawksworth and Wiens, 1995, in review).

DWARF MISTLETOE SURVEYS

In the Pacific Northwest, collecting data on dwarf mistletoe infestatons during stand examinations of all major conifer species beginning in 1972 had greatly increased the efficiency of dwarf mistletoe evaluation surveys (Pettinger and Johnson, 1973).

Trees within survey plots are given a dwarf mistletoe rating (DMR) using the "6 - class" system (Hawksworth 1977) based on visual observations. No attempt is made to identify the species of dwarf mistletoe present. Training is necessary for surveyors to recognize dwarf mistletoe on the various tree species. Dwarf mistletoe infection can be easily overlooked if large brooms are not present, or if infections occur higher in the crown than can be readily seen. Dwarf mistletoe infections in the lower canopy are evidence for its presence higher in the overstory.

Bloomberg and Smith (1982) point out that in western hemlock, it is virtually impossible to accurately estimate the number of dwarf mistletoe infections from the ground. Many of the lower infections in western hemlock produce few shoots of the dwarf mistletoe (Hawksworth and Wiens, 1995, in review), and may be difficult to see. In stands with dense shade, vigorous shoots of western hemlock dwarf mistletoe are often found only along margins of stands, on young trees in openings, or in higher branches of older trees (Hawksworth and Wiens, 1995, in review). On the other hand, large heavy branches, although uninfected, may have the appearance of witches' brooms.

SURVEY DATA

Bolsinger (1978) summarized survey data taken from 1963 to 1976 on inventory plots on commercial forest land in Oregon, Washington, and California. Oregon data was taken from 1964 to 1973; Washington from 1963 to 1968; and California from 1966 to 1976. He reported that occurrence of dwarf mistletoe on western and mountain hemlocks was scattered with extensive areas free of disease. In the hemlock type (3.25 million acres) 668 thousand acres, or 21 percent, were infested. Where western and mountain hemlocks occurred in other forest types (including Douglas-fir, true fir, and red alder), an additional 596 thousand acres were infested with hemlock dwarf mistletoe. In the hemlock type, of one million acres in "seedling/sapling/ poletimber," 10 percent of the acres were infested with hemlock dwarf mistletoe. Of 940 thousand acres in "small sawtimber," 18 percent were infested. Of 1.2 million acres in "large sawtimber," 32 percent were infested.

Demars (1980) reported that on the Deschutes National Forest, of 43 survey plots with hemlock (mostly mountain hemlock), 28% of plots had dwarf mistletoe, with 20% of the trees infected.

Even with silvicultural control intended to remove the disease, three young managed stands in coastal British Columbia had from 1 to 20 percent of the western hemlock infected with dwarf mistletoe (Hodge, et al., 1994). Hodge and coauthors expect the percentages to increase because as few as 10 infected residual trees can infect an entire hectare of new plantation within 15 years.

Appendix B includes summary tables of data from the timber inventory taken on National Forests within range of the northern spotted owl in Oregon and Washington, from 1976 to 1987. The tables provide data on the incidence of dwarf mistletoe only on western hemlock and mountain hemlock. Additional principal hosts for both subspecies of hemlock dwarf mistletoe include Pacific silver fir, subalpine fir, and noble fir. Incidence of dwarf mistletoe on species other than the hemlocks was not included in the summary tables to avoid counting other species of dwarf mistletoe. The resulting understatement of the distribution of hemlock dwarf mistletoe is in some cases dramatic. For example, field surveys have indicated extensive infection by western hemlock dwarf mistletoe in true fir in stands with little or no western hemlock, in northern Oregon Cascades, Mt. Hood National Forest (pers. communication, J. S. Beatty, 11/94, USDA For. Serv., Westside Technical Center, Troutdale, OR); and mountain hemlock dwarf mistletoe in stands of Pacific silver fir with little or no mountain hemlock in central Oregon Cascades, Willamette National Forest (pers. communication, R. L. Mathiasen, 2/95, Idaho Dept. Lands, Coeur d'Alene, ID). The summary tables represent a very **conservative** estimate of the distribution of hemlock dwarf mistletoe.

The following incidence data for dwarf mistletoe on hemlock is derived from the data in the summary tables (Appendix B). For National Forests within range of the northern spotted owl in Oregon and Washington, out of 2904 survey plots with hemlock, 774 plots, or 26.7 percent, had dwarf mistletoe on western or mountain hemlock. This contrasts with Bolsinger (1978) who reported and average of 21 percent incidence of hemlock dwarf mistletoe on western and mountain hemlock, based on inventory of the commercial forest lands in the northwest from 1966 to 1976.

Out of 2260 survey plots with western hemlock, 599 plots, or 26.5 percent, had dwarf mistletoe on western hemlock. Incidence ranged from zero on the Deschutes, Okanogan, and Siskiyou National Forests to 50.5 percent on the Olympic National Forest. Western hemlock did not occur on the survey plots on the Winema National Forest. Western hemlock occurred on less than 1 percent of the plots on the Deschutes National Forest, and less than 2 percent of those on the Okanogan. Although the Timber Inventory survey did not detect western hemlock dwarf mistletoe on the Siskiyou, D. J. Goheen reports that it is fairly common on some Districts on that Forest (pers. communication, 2/95, USDA For. Serv., Southwest Oregon Technical Center, Central Point, OR).

Out of 940 survey plots with mountain hemlock, 195 plots, or 20.7 percent, had dwarf mistletoe on mountain hemlock. Incidence ranged from 3.5 percent on the Mt. Hood National Forest to 47.8 percent on the Umpqua National Forest. Mountain hemlock did not occur on the survey plots on the Siuslaw and Siskiyou National Forests.

On all National Forest System lands in California, 0.05 percent of the cubic volume of mountain hemlock was infested with dwarf mistletoe (Forest Service, 1994). This is based on timber inventories of commercial timberland done in the 1980's. For example, on the Shasta-Trinity National Forest in northern California, 2.3 percent of the basal area per acre of mountain hemlock is infected with dwarf mistletoe, and 1.3 percent of the mountain hemlock trees per acre are infected (unpublished survey data, Zander, 1992, on file at Shasta-Trinity National Forest, Redding, CA). Most of the mountain hemlock occurs at high elevations, in wilderness or other administratively withdrawn areas not included in the inventories (pers. communication, G. A. DeNitto, 2/6/95, USDA Forest Service, Shasta-Trinity Forest Pest Management Office, Redding, CA). On the Shasta-Trinity, approximately 3,500 acres in the inventory had mountain hemlock as 10 percent or more of the stand. The vast majority of western hemlock is not on Federal land; some is already protected in the Smith River National Recreation Area. On non-Forest Service commercial timberlands, 3.1 percent of the cubic volume of western hemlock is infested with dwarf mistletoe (unpublished data, C. L. Bolsinger, 1994, USDA For. Serv., Pacific Northwest Station, Portland, OR).

FACTORS AFFECTING DISTRIBUTION

Stand or Site Factors

Buckland and Marples (1952) noted some patterns in the distribution of dwarf mistletoe in western hemlock stands. Dwarf mistletoe was less abundant on good sites, and more on poor sites where stands were open grown. In most even-age hemlock stands, dwarf mistletoe was not normally abundant. In uneven-aged stands or where hemlock approached "climax condition", dwarf mistletoe was frequently severe regardless of stand or site quality.

Around residual infected trees, dwarf mistletoe infection in the second growth is initially clumped. Even in severely infected stands, dwarf mistletoe tends to occur in patches, with infection centers surrounded by trees having little or no infection (Shea 1966). When dwarf mistletoe spreads into a young stand from the edge, the pattern is more irregular (Smith 1985).

In western hemlock in coastal Washington, Shea (1966) described stand histories with regard to natural disturbance:

> "Fire apparently played an important role in the development of dwarfmistletoe in present mature stands. Those that are essentally even-aged and of fire origin have little infection. The infections that are present commonly are around old infected residuals that escaped the fire, or around individual trees that apparently were infected by bird activities.
>
> Wind apparently had a smaller effect than fire on the incidence of infection in the present forest. Even-aged stands without apparent fire history varied greatly. Some showed considerable infection, whereas, others had little or none. Reconstruction of stand history suggested that the more heavily infected even-aged stands had had their overstories destroyued by wind after the present stand had been established and infected. On the other hand, the present stands with little or no infection probably had

their overstories completely destroyed by wind and came in after the wind throw. Stands of both kinds occur on ridges or slopes exposed to ocean storms, lending credence to this theory."

Climatic Factors

The most important climatic factors affecting dwarf mistletoe growth and reproduction are temperature and light. Rate of spread can also be affected by height growth of the host.

Bloomberg (1987) suggested reasons for the limitation of hemlock dwarf mistletoe in Alaska including a long latent period following infection, effects of severe climate on seed retention and infection, reduced height growth of residuals, and small size of advanced regeneration at release.

Baranyay and Smith (1974) reported early fall frosts as a significant factor in range limitation of dwarf mistletoe at high elevations, northern latitudes, and in frost pockets. Based on field observations and their studies, early freezing reduced the capacity of western hemlock dwarf mistletoe to transfer seed to host needles by 95 percent. For western hemlock dwarf mistletoe with fruit nearly mature, temperatures of -4.4 degrees C or colder damaged all the fruit. Fruit dried and fell off the tree within 2 weeks of the cold treatment. At -3.9 degrees C, 66 percent of the fruit was damaged. Only the current year's seed crop is affected by an early frost.

Mountain hemlock stands may experience freezing conditions every month of the year (pers. communication, J. S. Hadfield, USDA Forest Service, Eastern Washington Forest Health Office, Wenatchee, WA). It is unknown whether the subspecies on mountain hemlock may be adapted for fruit maturation at colder temperatures.

In studies on factors limiting Douglas-fir dwarf mistletoe west of the Cascades, Tinnin, Paquet, and Knutson (1976) considered "some of the ecological characteristics of A. tsugense ... because unlike A. douglasii, A. tsugense is widely distributed throughout western Oregon." They noted two general trends, 1) numbers of infections and seeds as well as host vigor, were greater by at least one order of magnitude in open sunlight than in shade; and 2) even in very dense shade, hemlock dwarf mistletoe produces some seeds. In the open, most hemlock dwarf mistletoe infections were in the mid to lower crown. Dense stands hinder seed movement and the shade reduces seed production.

For A. tsugense and other species, germination percent was better with light and warmth in studies by Knutson (1984).

DISCUSSION

Incidence

Incidence of hemlock dwarf mistletoe may have increased from 21 percent (Bolsinger 1978) to 26.7 percent (Appendix B). Considering the difficulty of correctly diagnosing dwarf mistletoe infections high in trees, the differences in survey results may not be significant. However, considering the difficulties of limiting hemlock dwarf mistletoe by silvicultural methods (see Traditional Silvicultural Management), an increase in incidence in managed stands would not be surprising.

The ROD states that most of the timber harvest will occur on matrix lands. On these lands, "at least 15 percent of the green trees on each regeneration harvest unit located on National Forest land must be retained." This requirement alone will probably result in an increase in the incidence of dwarf mistletoes. Even when the intent of the silvicultural prescription is to limit dwarf mistletoe in the regeneration, trees with latent (not yet visible) infections are often left as residuals. Infections are often inconspicuous, sometimes without any aerial shoots, until harvesting stimulates a bloom of dwarf mistletoe plants on the residual trees.

Spacial Distribution

According to Hawksworth and Wiens (1972), the distribution of a dwarf mistletoe is generally centered within the range of its principal host or hosts.

Many natural disturbance events tend to exhibit a clumped, rather than random or even/regular distribution. Clumps may tend to enlarge because of reproduction, but the initial distribution of an agent is often clumpy. Consider that forest fire and massive spruce beetle attack often leave varying sizes of patches of trees untouched, sometimes for no apparent biological reason.

In the expected natural distribution of an obligate parasite and its host, as the host becomes less frequent the parasite becomes much less frequent. Where the host is a major component across the landscape, given time for equilibrium with natural disturbances, its parasite would tend to occur in random clumps across the landscape. At any given point in time, populations of obligate parasites occur in patches across the host population, not occurring in other patches, for no habitat-related reason. With increasing time and without disturbance, the parasite populations expand. Eventually fire or other disturbances change the pattern.

Where the host is a minor component with many non-hosts between, the parasite might occur randomly among hosts. Where the host is occasional or infrequent, the distribution of the parasite might approach the Poisson distribution of a "rare and random" event. The data in the summary tables (Appendix B) from the timber inventory do not indicate whether the hemlock trees were widely dispersed with many non-host trees between hemlocks. Also, the timber inventory cannot include potentially subjective information such as stand history.

In nature one does not find every species everywhere that one might expect to find it, based on biological requirements. Especially for parasitic species, one finds sometimes extensive host populations without the parasite. This condition is temporary, as are all natural conditions. Whether the species ought to be there, in the sense that humans should put it there, is not a question of biological diversity.

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APPENDIX A

APPENDIX A

COMMENTS FROM "KNOWLEDGEABLE INDIVIDUALS"

The report on hemlock dwarf mistletoe in J2 includes a list of three "Knowledgeable Individuals" (provided by Nancy Fredricks and Dean Longrie, Forest Service, Pacific Northwest Region). Telephone and/or electronic communication with these individuals provided the comments that follow.

Delbert Wiens, PhD, University of Utah, Dept. Biology, Salt Lake City, UT

Dr. Wiens has coauthored many publications on dwarf mistletoe taxonomy. His recent work includes a revision of the classic Biology and Classification of Dwarf Mistletoes (Arceuthobium) which will be out as another Agricultural Handbook in 1995 (Hawksworth and Wiens, 1995, in review). He is also studying sex ratios in hemlock dwarf mistletoe (Wiens et al., 1995, in review), and has revisited many populations in the Pacific northwest since 1992. On January 18, 1995, Dr. Wiens provided the following statement:

"My Statement Regarding Rarity and Hemlock Dwarf Mistletoe

> I cannot consider hemlock dwarf mistletoe (Arceuthobium tsugense subsp. tsugense) to be rare, threatened, or endangered due to extirpation of the host (western hemlock). There are numerous extant populations of hemlock dwarf mistletoe throughout its extensive distribution from northern California to southeastern Alaska, and since 1992 I have collected this species over most of its distribution, revisiting many localities where it had been collected previously. It occurs in both old and new growth, and populations are often most robust in regenerating stands. Clear-cutting has obviously extirpated many populations of hemlock dwarf mistletoe and possibly fragmented others. This, however, has not resulted in rarity of the species, anymore than it has produced rarity of its host. It is entirely possible, but not documented to my knowledge, that the occasional "residuals" left following "clear-cutting" could be infected by dwarf mistletoes. Such trees are likely to be stunted and deformed, and therefore less desirable for timber. I should add that I am much interested in the maintenance of biodiversity, the phenomenon of rarity, and spontaneous extinction (see Nature 338: 65. 1989). Were hemlock dwarf mistletoe rare, I would so state."

However, dwarf mistletoe infection of residual trees left after "clear-cutting" is well-documented in Forestry and Plant Pathology literature (for example, Buckland and Marples 1952; Sterling 1962; Shea 1966; Simes et al., 1972; Stewart 1976; Bloomberg and Smith, 1982).

Rick Brown, National Wildlife Federation, Portland, OR

A telephone conversation with Rick Brown on August 2, 1994, provided the following information. Rick Brown began a masters thesis project on Douglas-fir dwarf mistletoe and did not finish earning the degree. His project involved a vegetative description of a particular west side Douglas-fir dwarf mistletoe site before it was logged. The thrust of the research was to ascertain why the incidence of Douglas-fir dwarf mistletoe was "so spotty" on the west side.

Rick Brown said he was "surprised to find hemlock dwarf mistletoe on the [Survey and Manage] list" and that it was "inappropriate". He also said that he thinks that there is "no problem" with hemlock dwarf mistletoe.

Jan Henderson, Area Ecologist, Mt. Baker-Snoqualmie and Olympic National Forests, USDA Forest Service, Mountlake Terrace, WA

Jan Henderson provided most of the information for the report on hemlock dwarf mistletoe in J2. During a conference call on July 18, 1994 (Jan Henderson, Diane Hildebrand, Nancy Fredricks, Don Goheen, Ken Denton, Jim Hadfield, Max Ollieu, Fay Shon), Jan indicated that the concern was the fragmentation in the host type causing fragmentation in the dwarf mistletoe population. He saw some significant gaps in the historic distribution, especially on the Mt. Baker-Snoqualmie National Forest.

On January 16, 1995, Jan Henderson provided additional comments reflecting on the preceding paragraph:

> "Also, at the time I operated under the understanding (that was false) that Arceuthobium tsugense was Survey & Manage [category] 3 or 4, not category 1. I don't believe category 1 is the appropriate category for this taxon. Mountain hemlock dwarf mistletoe (at least in Washington) probably SHOULD be here. This statement also overstates the correlation with old growth; while much more common in older stands, it its not always excluded from younger forests depending on moisture regime and type of disturbance."

OTHER KNOWLEDGEABLE INDIVIDUALS NOT LISTED IN J2

C. G. (Terry) Shaw, III, PhD, Project Leader: Pest Impact Assessment Technology, USDA Forest Service, Rocky Mountain Station, Fort Collins, CO

Dr. Shaw has many years of experience as a research plant pathologist all over the western United States and Alaska. After reviewing a draft of this paper, Dr. Shaw called (February 10, 1995) and said that he had no problem with a survey for mountain hemlock dwarf mistletoe. He said that the distribution of the mistletoe on mountain hemlock has been an interesting question ever since Weir first collected it in 1960. Dr. Shaw is willing to be contacted and referred to as a knowledgeable individual.

Robert L. Mathiasen, PhD, Plant Pathologist, Idaho Dept. Lands, Coeur d'Alene

Dr. Mathiasen has extensive knowledge of the biology and taxonomy of dwarf mistletoes throughout the western United States. After reviewing a draft of this paper, Dr. Mathiasen provided the following comments during a telephone conversation (February 14, 1995). He has only confirmed mountain hemlock dwarf mistletoe in one place in Washington, on the northeast side of Mt. Baker, near the ski area. This area is old forest; there has been no harvest because of the recreational values.

On the east side of the Cascades, he has seen some infestations of what he suspects is mountain hemlock dwarf mistletoe in both young and old trees, in partial cuts in young and old forests.

Dr. Mathiasen agreed to be quoted as follows:

> "Dwarf mistletoes are not old-growth associates. There is no basis for saying dwarf mistletoe of any type is only associated with old forests. Dwarf mistletoes, including mountain hemlock dwarf mistletoe, are host-dependent. The presence of a host and favorable climate are prerequisites for dwarf mistletoe occurrence. Susceptibility to infection has nothing to do with tree age; small trees can become infected and infection intensifies over time.
>
> Mountain hemlock dwarf mistletoe behaves the same way as western hemlock dwarf mistletoe: overstory inoculum will infect the understory; partial cutting and increasing light increase spread and intensification. Mountain hemlock dwarf mistletoe and western hemlock dwarf mistletoe have different host ranges and different elevational requirements, but the same epidemiology.
>
> We need to conduct a wide-spread survey for mountain hemlock dwarf mistletoe in Washington."

Craig Schmitt, Plant Pathologist, USDA Forest Service, Blue Mountain Pest Management Zone, LaGrande, OR

Craig Schmitt has many years of experience as a plant pathologist in Oregon and Washington. After reviewing a draft of this paper, he provided the following comments electronically on February 2, 1995:

> (Reply to: Hemlock dwarf mistletoe paper)
>
> "I've read through your documentation and I believe you've made an excellent case of the error in listing this species on the Survey and Manage List for the Westside Owl ROD. That inclusion was clearly based on misinformed opinion."

James S. Hadfield, Plant Pathologist and Center Manager, USDA Forest Service, Eastern Washington Forest Health Office, Wenatchee, WA

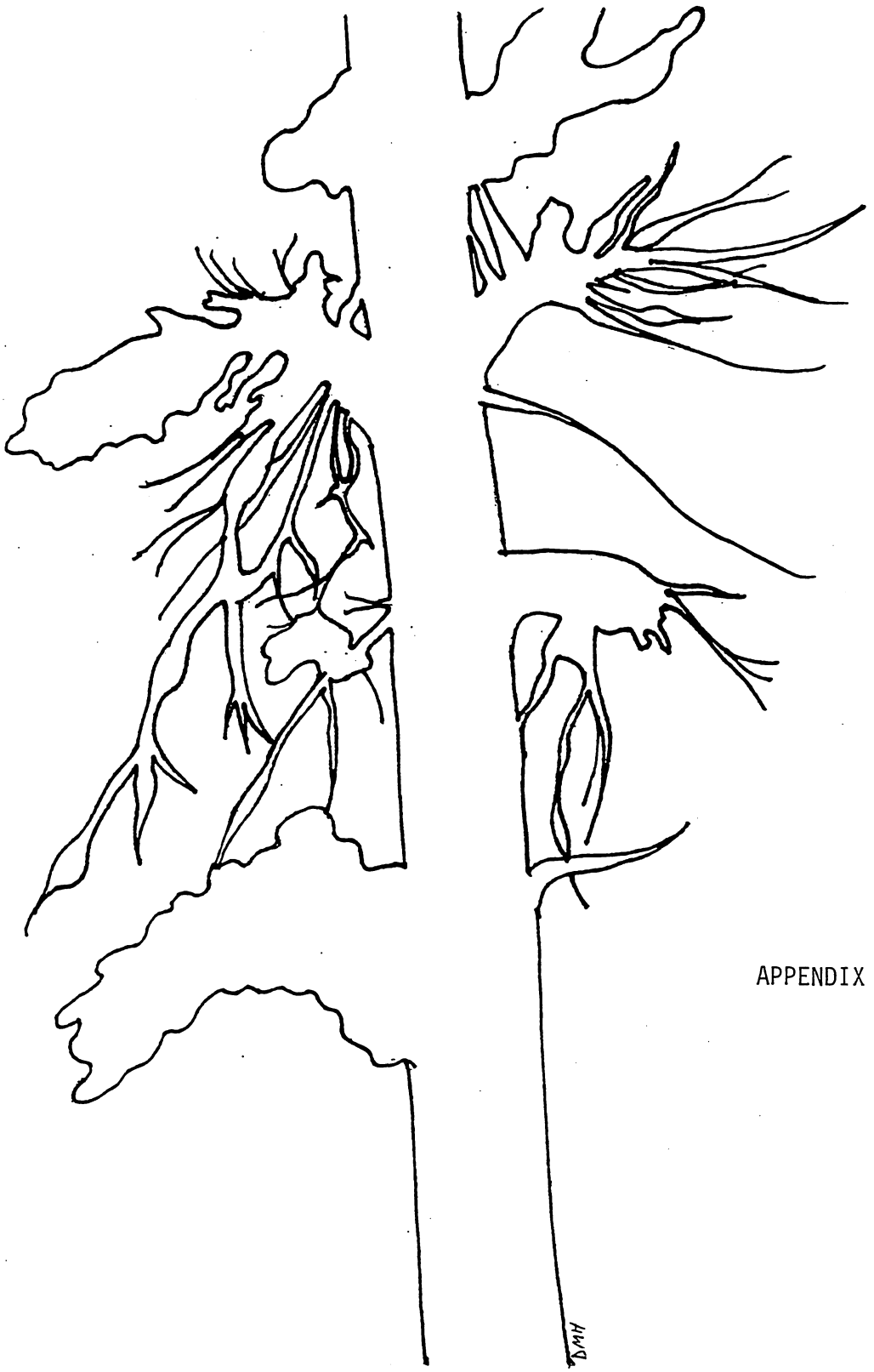
Jim Hadfield has many years of experience as a plant pathologist in Oregon and Washington. After reviewing a draft of this paper, he provided the following written comments on March 1, 1995:

> "I believe you have made a clear case for removing hemlock dwarf mistletoe from the "Survey and Manage" classification with this report.
>
> I believe the case has also been made to remove mountain hemlock dwarf mistletoe from the list. The inventory data show the parasite is widely distributed. However, because documentation of distribution in Washington appears to be sparse, I understand why it would be moved to category 4."

Don J. Goheen, PhD, Plant Pathologist, USDA Forest Service, Southwest Oregon Technical Center, Central Point, OR

In response to the ROD and the hemlock dwarf mistletoe description in J2, Dr. Goheen provided the following comments in May 1994:

> "Hemlock dwarf mistletoe is neither rare nor primarily limited to old or very old western hemlock stands. The Forest Inventory Plot information (Bolsinger 1978) indicates that 21 percent of the hemlock type in the Pacific Northwest has dwarf mistletoe infections, broken down as follows: pole size 10 percent; small sawtimber size 18 percent; and large sawtimber size 32 percent.
>
> My own experience of almost 19 years in the Region suggests that these figures are accurate for western Oregon, even though they were made 18 years ago. If anything, there has probably been a slight increase since 1978.
>
> Brooming associated with dwarf mistletoe infections in hemlock does tend to be greatest in older stands. However, I have seen spectacular brooms in trees that were 40 years old. I strongly suggest that inoculations to develop brooms are unnecessary. The brooms will develop whether we want them to or not. If we manage stands on long rotations, we'll have more than enough brooms.
>
> Dwarf mistletoe infections, especially heavy ones, can greatly influence stand development and structure. Forest Pest Management spent many years encouraging and even paying forest managers to "control" hemlock dwarf mistletoe to prevent the growth loss that the parasite causes. Infection in young stands, especially heavy infections with stand Dwarf Mistletoe Ratings in excess of 2.5, make it unlikely that hemlocks will develop large tree characteristics or that individual infected trees will even survive to ages much beyond 150 years.



APPENDIX B

APPENDIX B

HEMLOCK DWARF MISTLETOE IN PACIFIC NORTHWEST REGION NATIONAL FORESTS
WITHIN RANGE OF THE NORTHERN SPOTTED OWL
Data from the Regional Timber Inventory Database

compiled by Tom Gregg and Diane Hildebrand
January 20, 1995

The following summary tables include data from the timber inventory taken on Oregon and Washington forests from 1976 to 1987, with incidence of dwarf mistletoe on western and mountain hemlocks. The dwarf mistletoe on these species is Arceuthobium tsugense, with subspecies tsugense on western hemlock and subspecies mertensianae on mountain hemlock. Additional principal hosts for both subspecies of hemlock dwarf mistletoe include Pacific silver fir, subalpine fir, and noble fir.

The dwarf mistletoe survey in the timber inventory records the amount of dwarf mistletoe on each tree by tree species. No attempt is made to identify the species of dwarf mistletoe present. Incidence of dwarf mistletoe on species other than the hemlocks was not included in these summary tables to avoid counting other species of dwarf mistletoe. Therefore, the summary tables represent a very conservative estimate of the incidence of hemlock dwarf mistletoe.

Part I of the tables includes data for western and mountain hemlock combined; Part II includes data for just mountain hemlock; and Part III for western hemlock. For Oregon and Washington National Forests within range of the northern spotted owl, out of 2904 survey plots with hemlock, 774 plots, or 26.7 percent, had dwarf mistletoe on western or mountain hemlock. Out of 2260 survey plots with western hemlock, 599 plots, or 26.5 percent, had dwarf mistletoe on western hemlock. Out of 940 survey plots with mountain hemlock, 195 plots, or 20.7 percent, had dwarf mistletoe on mountain hemlock.

In the summary tables, the meanings of the column headings are as follows:

A. Total Plots: The total number of plots surveyed.
B. Plots w/ Hemlock: The total number of surveyed plots that contained hemlock.
C. Percent Plots w/ Hemlock: The number of plots with hemlock divided by the total number of plots, multiplied by 100, or B/A x 100.
D. Number of Hemlock: The actual number of hemlock trees measured in the survey plots.
E. Trees per Ac. Hemlock: For each plot, the database computes the number of hemlock trees per acre. The entry in the column is the average nubmer of hemlock trees per acre, computed as the sum of the hemlock trees per acre per plot, divided by the number of plots with hemlock, or [sigma TPA]/B.

F. Plots w/ Hemlock DM: The total number of survey plots that contained any hemlock with dwarf mistletoe.
G. Percent Plots w/ DM: The number of survey plots with hemlock dwarf mistletoe divided by the number of plots with hemlock, or F/B.
H. Number of Hemlock w/ DM: The actual number of hemlock trees with dwarf mistletoe surveyed.
I. Trees per Ac. w/DM: The average number of hemlock trees per acre with dwarf mistletoe in plots with hemlock dwarf mistletoe; for plots with hemlock dwarf mistletoe, the sum of the trees per acre (hemlock with dwarf mistletoe) per plots, divided by the number of plots with hemlock dwarf mistletoe, or [sigma TPA]/F.

PART I

WESTERN HEMLOCK AND MOUNTAIN HEMLOCK

Arceuthobium tsugense subs. tsugense and A. tsugense subsp. mertensianae
on Tsuga heterophylla and T. mertensiana

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY DMR GROUPS
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

Forest	Inventory Plots	Plots w/Hemlock Total	Plots w/Hemlock w/DM	Percent Plots w/DM	No of Hemlock	No. of Hemlock by DMR Class (Zero)	(1-2)	(3-4)	(5-6)
DES	617	117	20	17.1	4413	4010	144	201	58
GIP	355	273	59	21.6	2519	2142	178	105	94
MBS	380	365	129	35.3	10934	9866	545	303	220
MTH	610	462	76	16.5	6730	6358	148	113	111
OKA	353	13	1	7.7	406	401	1	4	0
OLY	478	460	232	50.4	18418	16097	1005	816	500
ROR	466	154	61	39.6	3388	2942	155	142	149
SIS	183	26	0	0	352	352	0	0	0
SIU	543	277	10	3.6	3822	3751	29	16	26
UMP	330	161	49	30.4	3751	3360	168	126	97
WEN	522	156	29	18.6	3697	3455	112	87	43
WIL	489	418	106	25.4	10146	9481	343	179	143
WIN	446	22	2	9.1	512	481	15	9	7

Out of 2904 survey plots with hemlock, 774 plots, or 26.7 percent, had dwarf mistletoe on hemlock.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY DIAMETER CLASS
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

Forest	Year Sampled	Number of Hemlock Trees	Number w/DM	Number w/DM by Diameter Class 0<1"	1<3"	3<13"	13<48"	>=48"
DES	1985	4010	403	0	1	116	286	0
GIP	1981	2142	377	0	5	66	298	8
MBS	1976	9866	1068	47	42	123	763	93
MTH	1986	6358	372	0	40	90	236	6
OKA	1977	401	5	0	0	0	5	0
OLY	1974	16097	2321	43	114	268	1719	177
ROR	1980	2942	446	26	70	181	167	2
SIS	1979	352	0	0	0	0	0	0
SIU	1987	3751	71	0	9	8	50	4
UMP	1980	3360	391	24	39	140	188	0
WEN	1977	3455	242	1	1	19	193	28
WIL	1981	9481	665	0	70	223	356	16
WIN	1981	481	31	0	0	4	27	0

DESCHUTES N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BEND	227	56	24.7	2110	884.6	8	14.3	248	90.0
CRESCENT	145	48	33.1	1879	980.6	11	22.9	148	103.5
FORT ROCK	143	6	4.2	168	440.9	0	.0	0	.0
SISTERS	102	7	6.9	256	2314.5	1	14.3	7	29.6

GIFFORD PINCHOT N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
MT ST HELENS NVM	7	5	71.4	56	81.4	3	60.0	28	20.5
MT ADAMS	99	73	73.7	633	120.2	10	13.7	39	16.1
PACKWOOD	64	62	96.9	639	163.9	16	25.8	85	54.4
RANDLE	103	86	83.5	806	163.2	14	16.3	95	31.9
WIND RIVER	82	47	57.3	385	105.7	16	34.0	130	50.7

MT BAKER-SNOQUALMIE N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BAKER RIVER	88	87	98.9	2067	344.0	40	46.0	315	36.9
DARRINGTON	73	72	98.6	2002	422.2	27	37.5	290	53.4
GLACIER	43	42	97.7	1279	526.2	10	23.8	47	32.3
MONTE CRISTO	30	30	100.0	1316	831.3	15	50.0	91	18.1
NORTH BEND	37	34	91.9	858	473.4	11	32.4	68	54.8
SKYKOMISH	42	40	95.2	1620	844.8	16	40.0	163	158.5
WHITE RIVER	67	60	89.6	1792	555.2	10	16.7	94	58.5

MT HOOD N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BARLOW	67	14	20.9	63	80.6	0	.0	0	.0
BEAR SPRINGS	59	53	89.8	904	320.4	1	1.9	2	7.4
CLACKAMAS	91	83	91.2	1076	236.2	5	6.0	28	63.6
COLUMBIA GORGE	141	128	90.8	2225	304.4	41	32.0	193	41.5
ESTACADA	83	64	77.1	864	214.4	10	15.6	40	31.3
HOOD RIVER	105	66	62.9	875	225.3	6	9.1	32	83.2
ZIG ZAG	64	54	84.4	723	214.0	13	24.1	77	61.4

OKANOGAN N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
TWISP	94	1	1.1	31	244.0	1	100.0	5	7.4
WINTHROP	102	12	11.8	375	606.8	0	.0	0	.0

OLYMPIC N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
HOODSPORT	74	70	94.6	1680	468.1	19	27.1	145	94.0
QUILCENE	98	91	92.9	3365	959.4	24	26.4	204	175.7
QUINAULT	117	117	100.0	7005	1324.7	99	84.6	1199	42.3
SHELTON	82	80	97.6	2151	507.7	30	37.5	121	25.4
SOLEDUCK	107	102	95.3	4217	873.6	60	58.8	652	55.9

ROGUE RIVER N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
APPLEGATE	127	12	9.4	417	682.9	5	41.7	38	50.3
BUTTE FALLS	85	28	32.9	480	447.2	12	42.9	118	214.5
PROSPECT	216	114	52.8	2491	573.3	44	38.6	290	117.9

SISKIYOU N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
GALICE	35	2	5.7	6	40.9	0	.0	0	.0
GOLD BEACH	44	1	2.3	15	450.0	0	.0	0	.0
POWERS	34	23	67.6	331	390.9	0	.0	0	.0

SIUSLAW N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
HEBO	180	119	66.1	2310	663.0	4	3.4	47	205.0
MAPLETON	143	62	43.4	444	173.3	0	.0	0	.0
ALSEA	72	10	13.9	120	551.6	2	20.0	10	82.5
OREGON DUNES	19	8	42.1	40	68.2	0	.0	0	.0
WALDPORT	129	78	60.5	908	271.1	4	5.1	14	19.7

UMPQUA N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
COTTAGE GROVE	24	18	75.0	618	916.4	3	16.7	56	384.9
TILLER	121	35	28.9	358	263.9	6	17.1	32	120.4
DIAMOND LAKE	115	78	67.8	2369	672.9	32	41.0	239	90.4
GLIDE	34	16	47.1	232	357.1	5	31.3	32	115.4
STEAMBOAT	36	14	38.9	174	275.6	3	21.4	32	162.4

WENATCHEE N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
CHELAN	60	2	3.3	5	75.0	0	.0	0	.0
CLE ELUM	39	30	76.9	800	401.1	8	26.7	41	17.4
ELLENSBURG	65	12	18.5	224	264.1	1	8.3	1	1.1
ENTIAT	77	6	7.8	220	711.7	1	16.7	26	82.4
LAKE WENATCHEE	79	42	53.2	1065	450.4	9	21.4	111	14.5
LEAVENWORTH	63	1	1.6	70	1156.0	0	.0	0	.0
NACHES	86	41	47.7	728	287.7	7	17.1	42	20.4
TIETON	53	22	41.5	585	435.9	3	13.6	21	9.1

WILLAMETTE N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BLUE RIVER	45	31	68.9	501	314.1	8	25.8	48	36.3
SWEET HOME	95	86	90.5	1475	363.0	25	29.1	121	46.4
DETROIT	63	60	95.2	1696	701.1	23	38.3	150	93.6
RIGDON	76	61	80.3	1549	460.9	13	21.3	85	68.8
LOWELL	36	34	94.4	457	325.5	4	11.8	7	15.0
MCKENZIE	65	52	80.0	1376	638.9	11	21.2	89	80.8
OAKRIDGE	109	94	86.2	3092	731.3	22	23.4	165	122.0

WINEMA N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK and MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
CHEMULT	118	1	.8	77	1232.7	0	.0	0	.0
KLAMATH	138	21	15.2	435	383.5	2	9.5	31	41.7

PART II

MOUNTAIN HEMLOCK DWARF MISTLETOE
Arceuthobium tsugense subs. mertensianae
on Tsuga mertensiana

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY DMR GROUPS
(MOUNTAIN HEMLOCK)

Forest	Inventory Plots	Plots w/Hemlock Total	Plots w/Hemlock w/DM	Percent Plots w/DM	No of Hemlock	No. of Hemlock by DMR Class (Zero)	(1-2)	(3-4)	(5-6)
DES	617	114	20	17.5	4352	3949	144	201	58
GIP	355	69	7	10.1	388	357	13	10	8
MBS	380	98	14	14.3	1333	1281	33	12	7
MTH	610	142	5	3.5	1598	1576	4	1	17
OKA	353	9	1	11.1	204	199	1	4	0
OLY	478	23	2	8.7	268	265	1	2	0
ROR	466	105	48	45.7	2378	1994	119	130	135
UMP	330	69	33	47.8	2345	2089	92	94	70
WEN	522	90	11	12.2	1817	1764	39	13	1
WIL	489	199	52	26.1	5542	5236	151	82	73
WIN	446	22	2	9.1	512	481	15	9	7

Out of 940 survey plots with mountain hemlock, 195 plots, or 20.7 percent, had dwarf mistletoe on mountain hemlock.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY DIAMETER CLASS
(MOUNTAIN HEMLOCK)

Forest	Year Sampled	Number of Hemlock Trees	Number of Hemlock w/DM	Number w/DM by Diameter Class 0<1"	1<3"	3<13"	13<48"	>=48"
DES	1985	3949	403	0	1	116	286	0
GIP	1981	357	31	0	1	10	20	0
MBS	1976	1281	52	0	0	1	44	7
MTH	1986	1576	22	0	2	5	15	0
OKA	1977	199	5	0	0	0	5	0
OLY	1974	265	3	0	0	0	3	0
ROR	1980	1994	384	22	57	153	151	1
UMP	1980	2089	256	8	9	90	149	0
WEN	1977	1764	53	0	0	8	44	1
WIL	1981	5236	306	0	31	120	155	0
WIN	1981	481	31	0	0	4	27	0

DESCHUTES N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BEND	227	56	24.7	2109	882.8	8	14.3	248	90.0
CRESCENT	145	46	31.7	1821	983.0	11	23.9	148	103.5
FORT ROCK	143	6	4.2	168	440.9	0	.0	0	.0
SISTERS	102	6	5.9	254	2695.2	1	16.7	7	29.6

GIFFORD PINCHOT N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
MT ST HELENS NVM	7	1	14.3	2	31.3	0	.0	0	.0
MT ADAMS	99	37	37.4	238	79.5	2	5.4	3	10.7
PACKWOOD	64	12	18.8	47	59.6	1	8.3	10	58.8
RANDLE	103	16	15.5	81	86.2	1	6.3	4	43.9
WIND RIVER	82	3	3.7	20	97.7	3	100.0	14	57.4

MT BAKER-SNOQUALMIE N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BAKER RIVER	88	30	34.1	377	143.9	6	20.0	21	3.7
DARRINGTON	73	12	16.4	159	115.8	2	16.7	13	24.4
GLACIER	43	19	44.2	251	174.9	2	10.5	2	5.9
MONTE CRISTO	30	4	13.3	64	144.4	1	25.0	8	16.5
NORTH BEND	37	7	18.9	125	253.7	1	14.3	5	22.0
SKYKOMISH	42	15	35.7	246	248.4	1	6.7	1	2.7
WHITE RIVER	67	11	16.4	111	182.9	1	9.1	2	1.5

MT HOOD N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BARLOW	67	8	11.9	44	109.2	0	.0	0	.0
BEAR SPRINGS	59	23	39.0	261	276.2	0	.0	0	.0
CLACKAMAS	91	52	57.1	722	250.3	4	7.7	15	27.9
COLUMBIA GORGE	141	1	.7	3	11.2	0	.0	0	.0
ESTACADA	83	20	24.1	151	133.0	1	5.0	7	53.8
HOOD RIVER	105	25	23.8	244	103.9	0	.0	0	.0
ZIG ZAG	64	13	20.3	173	134.8	0	.0	0	.0

OKANOGAN N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
TWISP	94	1	1.1	31	244.0	1	100.0	5	7.4
WINTHROP	102	8	7.8	173	426.5	0	.0	0	.0

OLYMPIC N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
HOODSPORT	74	10	13.5	87	150.3	0	.0	0	.0
QUINAULT	117	2	1.7	38	227.7	2	100.0	3	2.8
SHELTON	82	10	12.2	142	152.0	0	.0	0	.0
SOLEDUCK	107	1	.9	1	.8	0	.0	0	.0

ROGUE RIVER N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
APPLEGATE	127	12	9.4	416	680.4	5	41.7	38	50.3
BUTTE FALLS	85	17	20.0	321	476.1	10	58.8	96	196.5
PROSPECT	216	76	35.2	1641	576.9	33	43.4	250	138.3

SISKIYOU N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

No mountain hemlock surveyed on this Forest.

SIUSLAW N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

No mountain hemlock surveyed on this Forest.

UMPQUA N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
TILLER	121	2	1.7	18	108.5	1	50.0	1	3.1
DIAMOND LAKE	115	64	55.7	2260	775.7	31	48.4	234	92.6
STEAMBOAT	36	3	8.3	67	425.7	1	33.3	21	181.4

WENATCHEE N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
CHELAN	60	2	3.3	4	60.0	0	.0	0	.0
CLE ELUM	39	15	38.5	296	416.9	3	20.0	3	1.9
ELLENSBURG	65	11	16.9	200	264.8	1	9.1	1	1.1
ENTIAT	77	4	5.2	170	786.8	1	25.0	26	82.4
LAKE WENATCHEE	79	24	30.4	478	339.1	4	16.7	19	10.5
LEAVENWORTH	63	1	1.6	70	1156.0	0	.0	0	.0
NACHES	86	18	20.9	217	192.1	1	5.6	1	2.5
TIETON	53	15	28.3	382	449.6	1	6.7	3	8.7

WILLAMETTE N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BLUE RIVER	45	15	33.3	267	319.9	4	26.7	30	33.7
SWEET HOME	95	18	18.9	129	114.5	5	27.8	8	12.0
DETROIT	63	21	33.3	329	374.2	4	19.0	15	54.5
RIGDON	76	45	59.2	1239	499.5	11	24.4	55	71.8
MCKENZIE	65	24	36.9	891	892.7	7	29.2	54	93.3
OAKRIDGE	109	76	69.7	2687	780.0	21	27.6	144	114.3

WINEMA N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(MOUNTAIN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
CHEMULT	118	1	.8	77	1232.7	0	.0	0	.0
KLAMATH	138	21	15.2	435	383.5	2	9.5	31	41.7

PART III

WESTERN HEMLOCK
Arceuthobium tsugense subsp. tsugense
on Tsuga heterophylla

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY DMR GROUPS
(WESTERN HEMLOCK)

Forest	Inventory Plots	Plots w/Hemlock Total	Plots w/Hemlock w/DM	Percent Plots w/DM	No of Hemlock	No. of Hemlock by DMR Class (Zero)	(1-2)	(3-4)	(5-6)
DES	617	6	0	0	61	61	0	0	0
GIP	355	234	53	22.6	2131	1785	165	95	86
MBS	380	323	118	36.5	9601	8585	512	291	213
MTH	610	375	73	19.5	5132	4782	144	112	94
OKA	353	7	0	0	202	202	0	0	0
OLY	478	457	231	50.5	18150	15832	1004	814	500
ROR	466	59	14	23.7	1010	948	36	12	14
SIS	183	26	0	0	352	352	0	0	0
SIU	543	277	10	3.6	3822	3751	29	16	26
UMP	330	99	16	16.2	1406	1271	76	32	27
WEN	522	100	20	20	1880	1691	73	74	42
WIL	489	297	64	21.5	4604	4245	192	97	70

Out of 2260 plots with western hemlock, 599 plots, or 26.5 percent, had dwarf mistletoe on western hemlock.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY DIAMETER CLASS
(WESTERN HEMLOCK)

Forest	Year Sampled	Number of Hemlock Trees	Number w/DM	Number w/DM by Diameter Class 0<1"	1<3"	3<13"	13<48"	>=48"
DES	1985	61	0	0	0	0	0	0
GIP	1981	1785	346	0	4	56	278	8
MBS	1976	8585	1016	47	42	122	719	86
MTH	1986	4782	350	0	38	85	221	6
OKA	1977	202	0	0	0	0	0	0
OLY	1974	15832	2318	43	114	268	1716	177
ROR	1980	948	62	4	13	28	16	1
SIS	1979	352	0	0	0	0	0	0
SIU	1987	3751	71	0	9	8	50	4
UMP	1980	1271	135	16	30	50	39	0
WEN	1977	1691	189	1	1	11	149	27
WIL	1981	4245	359	0	39	103	201	16

DESCHUTES N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BEND	227	1	.4	1	100.0	0	.0	0	.0
CRESCENT	145	3	2.1	58	617.2	0	.0	0	.0
SISTERS	102	2	2.0	2	15.2	0	.0	0	.0

GIFFORD PINCHOT N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
MT ST HELENS NVM	7	4	57.1	54	94.0	3	75.0	28	20.5
MT ADAMS	99	49	49.5	395	119.1	8	16.3	36	17.5
PACKWOOD	64	57	89.1	592	165.7	15	26.3	75	54.1
RANDLE	103	78	75.7	725	162.3	13	16.7	91	30.9
WIND RIVER	82	46	56.1	365	101.7	14	30.4	116	45.6

MT BAKER-SNOQUALMIE N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BAKER RIVER	88	73	83.0	1690	350.8	35	47.9	294	41.6
DARRINGTON	73	68	93.2	1843	426.6	27	39.7	277	51.6
GLACIER	43	35	81.4	1028	536.5	8	22.9	45	38.9
MONTE CRISTO	30	27	90.0	1252	902.3	14	51.9	83	18.2
NORTH BEND	37	31	83.8	733	461.9	10	32.3	63	58.0
SKYKOMISH	42	34	81.0	1374	884.3	15	44.1	162	168.9
WHITE RIVER	67	55	82.1	1681	569.1	9	16.4	92	64.8

MT HOOD N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BARLOW	67	7	10.4	19	36.4	0	.0	0	.0
BEAR SPRINGS	59	44	74.6	643	241.6	1	2.3	2	7.4
CLACKAMAS	91	45	49.5	354	146.3	3	6.7	13	68.8
COLUMBIA GORGE	141	128	90.8	2222	304.3	41	32.0	193	41.5
ESTACADA	83	58	69.9	713	190.7	9	15.5	33	28.7
HOOD RIVER	105	46	43.8	631	266.8	6	13.0	32	83.2
ZIG ZAG	64	47	73.4	550	208.6	13	27.7	77	61.4

OKANOGAN N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
WINTHROP	102	7	6.9	202	552.8	0	.0	0	.0

OLYMPIC N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
HOODSPORT	74	69	93.2	1593	453.0	19	27.5	145	94.0
QUILCENE	98	91	92.9	3365	959.4	24	26.4	204	175.7
QUINAULT	117	116	99.1	6967	1332.1	98	84.5	1196	42.6
SHELTON	82	79	96.3	2009	494.9	30	38.0	121	25.4
SOLEDUCK	107	102	95.3	4216	873.6	60	58.8	652	55.9

ROGUE RIVER N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
APPLEGATE	127	1	.8	1	30.0	0	.0	0	.0
BUTTE FALLS	85	11	12.9	159	402.7	2	18.2	22	304.1
PROSPECT	216	47	21.8	850	457.8	12	25.5	40	52.0

SISKIYOU N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
GALICE	35	2	5.7	6	40.9	0	.0	0	.0
GOLD BEACH	44	1	2.3	15	450.0	0	.0	0	.0
POWERS	34	23	67.6	331	390.9	0	.0	0	.0

SIUSLAW N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
HEBO	180	119	66.1	2310	663.0	4	3.4	47	205.0
MAPLETON	143	62	43.4	444	173.3	0	.0	0	.0
ALSEA	72	10	13.9	120	551.6	2	20.0	10	82.5
OREGON DUNES	19	8	42.1	40	68.2	0	.0	0	.0
WALDPORT	129	78	60.5	908	271.1	4	5.1	14	19.7

UMPQUA N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
COTTAGE GROVE	24	18	75.0	618	916.4	3	16.7	56	384.9
TILLER	121	33	27.3	340	273.3	5	15.2	31	143.9
DIAMOND LAKE	115	19	16.5	109	149.5	1	5.3	5	22.0
GLIDE	34	16	47.1	232	357.1	5	31.3	32	115.4
STEAMBOAT	36	13	36.1	107	198.6	2	15.4	11	152.9

WENATCHEE N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
CHELAN	60	1	1.7	1	30.0	0	.0	0	.0
CLE ELUM	39	25	64.1	504	231.2	6	24.0	38	22.3
ELLENSBURG	65	3	4.6	24	85.5	0	.0	0	.0
ENTIAT	77	2	2.6	50	561.6	0	.0	0	.0
LAKE WENATCHEE	79	29	36.7	587	371.6	6	20.7	92	14.8
NACHES	86	30	34.9	511	278.0	6	20.0	41	23.3
TIETON	53	10	18.9	203	284.6	2	20.0	18	9.3

WILLAMETTE N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM
BLUE RIVER	45	25	55.6	234	197.6	7	28.0	18	22.2
SWEET HOME	95	82	86.3	1346	355.5	20	24.4	113	54.9
DETROIT	63	56	88.9	1367	610.9	21	37.5	135	92.2
RIGDON	76	24	31.6	310	235.0	4	16.7	30	25.9
LOWELL	36	34	94.4	457	325.5	4	11.8	7	15.0
MCKENZIE	65	34	52.3	485	347.0	4	11.8	35	58.9
OAKRIDGE	109	42	38.5	405	225.3	4	9.5	21	70.7

WINEMA N.F.

DISTRIBUTION OF HEMLOCK DWARF MISTLETOE BY FOREST AND DISTRICT
(WESTERN HEMLOCK)

District	Total Plots	Plots w/ Hemlock	Percent Plots w/ Hemlock	Number of Hemlock	Trees Per Ac. Hemlock	Plots w/ Hemlock DM	Percent Plots /w DM	Number Hemlock w/DM	Trees Per Ac. w/DM

No plots with western hemlock surveyed on this Forest.

APPENDIX C

Date: February 24, 1995

To: Cheryl McCaffrey, Leader
Survey & Manage Work Group

Subject: Request for Change in Status of ARCEUTHOBIUM TSUGENSE

This letter is a formal proposal for a change in the list of species (Table C3) requiring mitigation under the Survey and Manage guidelines. The ROD (p. 37) allows "such changes as appropriate in order to assure the continuing attainment of the purposes of the plan... The REO will forward proposals, along with recommendations, to the RIEC for action."

The Survey and Manage Work Group requests a change in status for Arceuthobium tsugense, a species currently listed as requiring survey and manage strategies 1 and 2. We recommend that A. tsugense be removed, and in its place A. tsugense subsp. mertensianae be listed as requiring survey and manage strategy 4 only in the State of Washington. We recommend that A. tsugense subsp. tsugense be removed completely from any mitigation requirements under the survey and manage guidelines.

The Survey and Manage Work Group will not compile known site data or proceed with the development of management direction and survey protocols until RIEC renders a decision on the status of A. tsugense, hemlock dwarf mistletoe.

Documentation in support of these recommendations is attached: 1. "Concerns Regarding A. tsugense subsp. mertensianae," by Jan Henderson; and 2. "A. tsugense, Hemlock Dwarf Mistletoe," by Diane Hildebrand. During FEMAT, Jan Henderson's original concern was for A. tsugense subsp. mertensianae in Washington, but at that time it was not possible to separate out subspecies and geographic regions.

On February 15, 1995, Russ Holmes, Jan Henderson, Diane Hildebrand, and Jerry Beatty came to consensus on the above recommendations. They applied the process used during FEMAT to each of the subspecies separately, and the results follow.

Association with Late-Successional and Old-Growth Forests

Dwarf mistletoes do not require habitat components that are contributed by late successional and old-growth forests (LSOG). Dwarf mistletoe infection within host trees and within stands tends to intensify over time. Hence, Jan Henderson considers both western and mountain hemlock dwarf mistletoes as significantly more abundant in LSOG (Criterion 1 of FEMAT Table IV-6: Criteria for species closely associated with LSOG). Plant pathologists consider this criterion as having little meaning for dwarf mistletoes, because of their well documented persistence and intensification in young, cutover, and second growth stands. Some of the largest numbers of infected trees per acre can be found in young stands managed without adequate regard for dwarf mistletoe.

Arceuthobium tsugense subsp. tsugense (Western hemlock dwarf mistletoe)

Western hemlock dwarf mistletoe is common and well distributed, and is considered not at risk of being extirpated throughout the range of the northern spotted owl. Habitat is of sufficient quality, distribution, and abundance to allow the species population to stabilize, well distributed across federal lands. Spacial gaps in incidence of western hemlock dwarf mistletoe are consistent with those known historically. These conditions correspond to Outcome A of FEMAT Table IV-7: Description of outcomes for rating the level of habitat support for populations. No survey and manage strategy is necessary or appropriate for western hemlock dwarf mistletoe throughout the ROD area.

Arceuthobium tsugense subsp. mertensianae (Mountain hemlock dwarf mistletoe)

In Oregon and northern California, mountain hemlock dwarf mistletoe is considered not at risk of being extirpated. In Oregon, mountain hemlock dwarf mistletoe is common and well distributed, and in northern California it is less common. Habitat in Oregon and northern California is of sufficient quality, distribution, and abundance to allow the species population to stabilize, consistent with its historic distribution across federal lands (Outcome A, FEMAT Table IV-7). No survey and management strategy is necessary or appropriate for mountain hemlock dwarf mistletoe in Oregon and northern California.

In Washington, only four sites with mountain hemlock dwarf mistletoe have been confirmed: one on Mt. Rainier, one on the Mt. Baker-Snoqualmie NF, and two on the Olympic NF. Of approximately 650 ecology program plots in the mountain hemlock zone, mountain hemlock dwarf mistletoe was only recorded once. The Forest Service timber inventory includes 35 plots with mountain hemlock dwarf mistletoe in Washington (on the Gifford Pinchot, Mt. Baker-Snoqualmie, Okanogan, Olympic, and Wenatchee National Forests), and these need to be confirmed.

The three confirmed sites of mountain hemlock dwarf mistletoe on the National Forests are very old forests in cold wet areas with heavy snowpack, in contrast with the generally warmer and drier sites in Oregon. The distribution and taxonomic status of this dwarf mistletoe in the northern part of its range (Washington) is not understood. Survey, with professional verification, is needed for mountain hemlock dwarf mistletoe where its hosts are found throughout Washington. Forest Insects and Diseases (FID), USDA Forest Service, Portland Regional Office and Westside Technical Center, intend to begin survey and identification work in summer 1995.

The four confirmed sites are all in reserves or otherwise excluded from management impacts. The potential risks to the viability of mountain hemlock dwarf mistletoe in Washington relate to its apparent rarity, and susceptibility to large intense fire events.

Survey and manage strategies 1 through 3 were developed for species that need habitat protection to maintain persistence of the species. Strategy 4 is intended to develop new information about a taxon. Strategy 4 is appropriate as a mitigation requirement for mountain hemlock dwarf mistletoe in Washington.

Respectfully submitted,

Diane M. Hildebrand
Plant Pathologist, FID, Forest Service RO

Jan Henderson
Area Ecologist, Mt. Baker-Snoqualmie and Olympic National Forests

Jerome S. Beatty
Program Manager, FID/NR Westside Technical Center

Russ Holmes
Botanist, BLM, Vascular Plant Team Leader, S&M